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ABSTRACT

This report presents a synthesis of information about assistive technology (AT) characteristics, for the purpose of identifying design characteristics that contribute to the quality of AT devices used by school children with disabilities. The first section provides a brief overview of AT, including a definition. The second section describes educational goals for using AT and barriers that inhibit the use of AT, such as lack of awareness of AT, lack of training, and insufficient funding. The third section presents information on the most popular AT devices organized into groups based on their level of technology. Several databases which can provide more information are identified. The fourth section focuses on the area of augmentative communication as an example of assessing the need for AT. The fifth section synthesizes information about effective characteristics of AT devices and describes the limitations of the synthesis. An extensive table allows comparison of conclusions of 32 evaluative studies. The last section presents recommendations and guidelines to help consumers select quality AT and to help developers design quality AT for school children. An appendix offers definitions of design characteristics. (Contains 49 references.) (DB)

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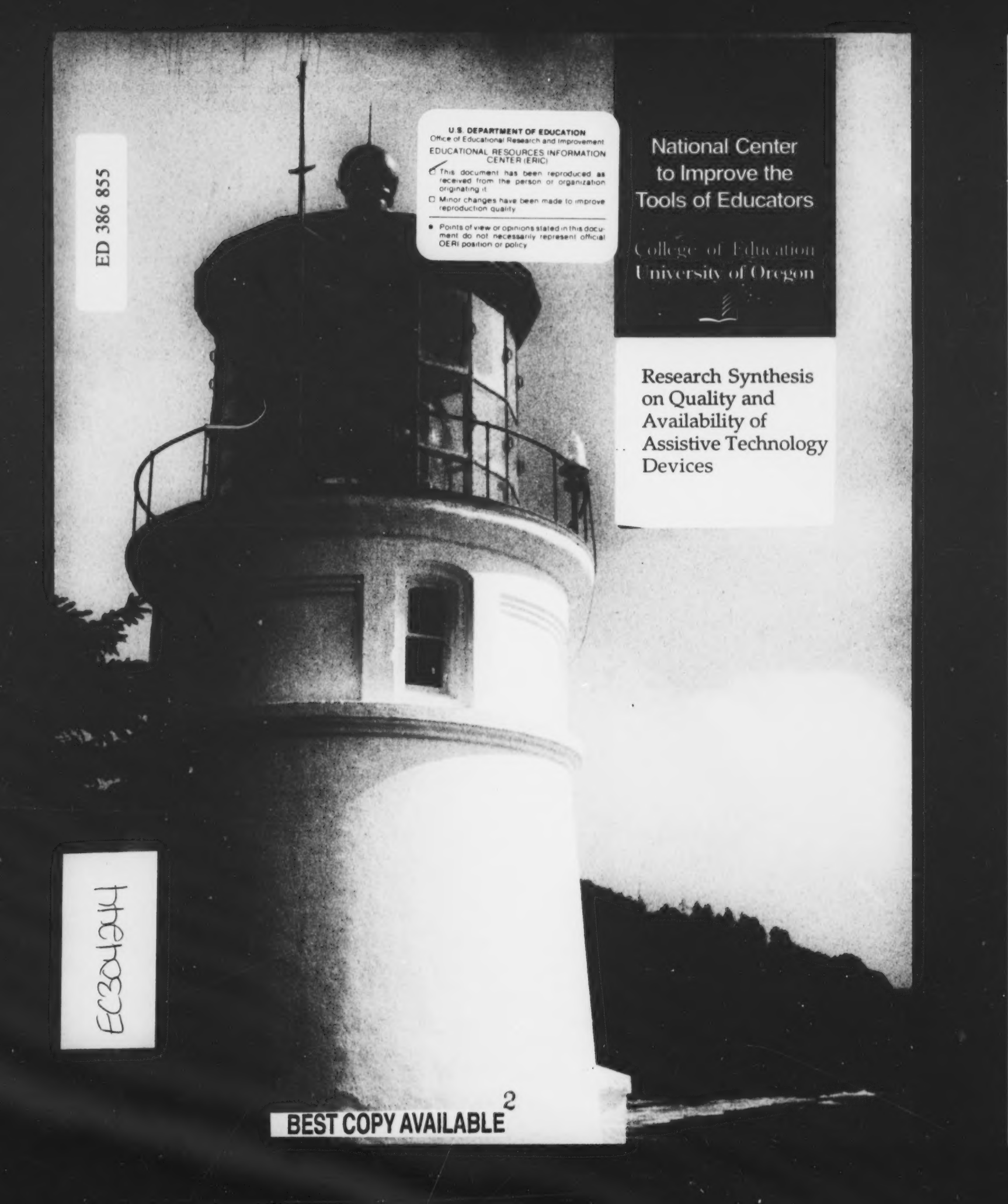

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Research Synthesis on Quality and Availability of Assistive Technology Devices

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Research Synthesis on Quality and Availability of Assistive Technology Devices

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QUALITY AND AVAILABILITY OF ASSISTIVE TECHNOLOGY DEVICES

PURPOSE AND ORGANIZATION

Rapid advances in technology have increased the availability of Assistive Technology[1] (AT) with a corresponding increase in demand for quality. The quality of AT, which varies widely (Enders & Hall, 1990), is related to the characteristics of AT devices and how devices match the needs of persons with disabilities. Matching a device to a person with disabilities requires an evaluation, which is usually conducted by a team of professionals and the consumer. Although this evaluation process is briefly described in this report, the primary focus of the report is on determining which device characteristics contribute to the quality of AT. (An example of an AT device characteristic is Reliability, i.e., will the device continue to function consistently over a period of time.)

To help determine device characteristics, a synthesis of information about AT device characteristics was conducted and is contained in this report. The information for the synthesis was derived from research, clinical observation, and descriptive reports and articles. Information from the synthesis was used to identify design characteristics that contribute to the quality of AT devices. Information about these device characteristics will be summarized and made available to designers and manufacturers to help increase the quality of AT devices. This information may also help consumers and providers improve the quality of evaluations used to select AT devices.

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[1]Assistive Technology (AT) refers to the devices and related services used to help persons with disabilities perform life functions.

This report was commissioned by the staff of the National Center to Improve the Tools of Educators (NCITE) located at the University of Oregon. The major focus of NCITE is to improve the quality of technology used by school-age children who have disabilities. Correspondingly, the synthesis described in this report is limited to information about the use of AT by school-age children. Also, information about AT used by persons with vision and hearing impairments is excluded because this information is contained in other reports commissioned by NCITE.

The report is divided into six major sections and is organized as follows: (1) the Introduction provides a brief overview of AT; (2) the Educational Uses of AT section describes educational goals for using AT and barriers that inhibit the use of AT; (3) the Popular AT Devices section presents information about the most popular AT devices and how they can be located; (4) the Assessing the Need for AT section uses the area of augmentative communication as an example of assessing the need for AT; (5) the Characteristics of Effective AT Devices section provides a synthesis of information about effective characteristics of AT devices, and describes the limitations of the synthesis; and (6) the Recommendations section presents recommendations and guidelines to help consumers select quality AT and to help developers design quality AT for school-age children.

INTRODUCTION

AT devices and services have been used for centuries, but the viability of their use has greatly increased with advances in technology. In the United States attention toward AT has grown dramatically with the passage of Public Law 100-407 (The Technology Related Assistance Act, "The Tech Act" (1988)). The Tech Act provides state funding for conducting statewide

needs assessments, establishing statewide or community-based systems that help individuals with disabilities use AT devices or services, providing public awareness programs about AT, supporting training activities that relate to the provision of AT, and developing and operating systems for improving public access to information about AT.

Potentially, technology can improve the lives of all people. For persons with disabilities, AT can make many life functions possible. For many school-age children with disabilities, AT makes education possible. With regard to school-age children, a generally accepted definition of AT is included in the Individuals with Disabilities Education Act (1990).

> A. The term assistive technology device means any item, piece of equipment, or product system, whether acquired commercially or off-the-shelf, modified, or customized that is used to increase, maintain, or improve the functional capabilities of individuals with disabilities.
>
> B. The term assistive technology service means any service that directly assists an individual with a disability in the selection, acquisition, or use of an assistive technology device.

AT is redefining what is possible for school children with a wide range of cognitive and physical disabilities. For example, access to education becomes possible for many children through the use of augmentative communication and mobility devices. Without AT, children who cannot verbally communicate are denied many social and learning opportunities inherent in a formal education. With limited mobility, children may be unable to attend school. Other technologies, such as learning technologies are important, but for many children, AT is the key to receiving an education and may be viewed as the most important form of technology assistance for students with disabilities.

EDUCATIONAL USES OF AT

This section describes some of the major goals school-age children may have for using AT and some of the barriers they may encounter in acquiring and using AT. Emphasis is placed on mandates of recent legislation and potential barriers to meeting these mandates.

Educational Goals for Using AT

The ultimate goal for using AT is attaining independence. In the case of school-age children, a major goal is accessing education through augmentative communication, vision and hearing enhancement, and mobility assistance. The instructional goals for school-age children with disabilities are defined in the child's individual education program (IEP). Recent legislation (Individuals with Disabilities Education Act) and subsequent interpretations (Shragg, 1990; cited in SMART Exchange, 1990) require AT to be included in the child's IEP. As the quality and availability of AT increases, the IEP requirement will become more viable. The following provides more information about the AT requirements of this legislation.

In August 1990, the Office of Special Education Programs (OSEP) issued a policy statement saying that AT should be considered part of the process of developing a child's IEP. A Summary of the OSEP policy follows:

- School districts cannot presumptively deny AT to a student with a disability.
- The need for AT must be considered on an individual, case-by-case basis in the development of the student's IEP.
- AT can be part of special education or a related service.
- AT can also be a form of supplementary aid or service utilized to facilitate a child's education in a regular education environment.

- If participants on the IEP team determine a child requires AT in order to receive a free, appropriate public education and designate such AT as either special education or a related service, then the services must be provided at no cost to the parents.
- There are three places in the IEP where AT may appear: (1) annual goals and short-term objectives, (2) supplementary aids and services, and (3) related services.

With regard to AT, the requirements of The Individuals with Disabilities Education Act will assist school-age children to meet their educational goals. At the same time, however, these requirements place financial and time burdens on the school system. As the demand for AT increases, the barriers to acquiring AT become more visible.

Barriers to Using AT

As noted, the promise for AT is great. Acquiring AT, however, is often hindered by one or more barriers. Parker, Buckley, Turesdell, Riggo, Collins, & Boardman (1990) observed that "the potential of technological advances is not as easily transmitted to teachers than to habilitative therapists of children with disabling conditions. Outside of a few major centers, there appear to be significant barriers to the consistent utilization of assistive technologies by these front line providers" (p. 2). The following are major barriers to the acquisition of AT:

1. Lack of awareness of AT by consumers and professionals,
2. Lack of training in AT,
3. Insufficient funding or lack of knowledge about the access to funding for AT, and
4. The problem of school districts not allowing AT to leave the classroom.

Lack of Awareness of AT

The barriers of lack of awareness and lack of training was considered in a study by Parker et al. (1990). Parker and colleagues conducted a survey designed to evaluate the

perceived barriers to the utilization of AT in a sample of therapists and teachers of children with sensory and other disabilities. The survey respondents identified four major problems that resulted in barriers to obtaining and using AT. Two of these problems were lack of awareness and lack of training about AT. When asked about solutions, the respondents said they needed training in the use of AT and they needed more information with regard to AT. The passage of The Technology Assistance Act (1988) was based in large part on the need for awareness and training in AT. Two of the seven major components of Title I of this act deal with awareness and training. Title II of the act deals exclusively with training. Essentially all of the currently funded state projects under The Technology Assistance Act (1988) have training and awareness components (UATP survey, 1991).

Because AT is required as part of a child's IEP, the increased use of AT will require a substantial training effort for students, teachers, counselors, and administrators. Teachers and other related personnel must be made aware of the conditions under which AT must operate, and they must be trained to integrate AT devices into the classroom. As noted by Scherer and Mckee (1992a),

> Some special educators who do not perceive themselves as technically skilled may not only avoid learning about new technologies, but may downplay their usefulness and not present them as viable options. If they have had unpleasant experiences in introducing new technologies into the classroom, or participated in too many overly technical workshops, they have become soured on updating or broadening their technical skills. (p. 2)

Awareness and training about AT is receiving a great deal of attention and the associated barriers should be progressively minimized as the state projects meet their objectives.

Lack of Funding for AT

Parker et al. (1990) identify funding as a barrier to acquiring AT but do not identify solutions. Solutions to this barrier are scarce. Reducing the funding barrier is dependent to a great extent on the availability of funds, which in turn is dependent on widely fluctuating state and national economies. Even though there are numerous sources for funding AT for students with disabilities, many of these sources are not pursued because teachers and administrators are not familiar with the availability of funds and the procedures for requesting funding. Additionally, funding for school-age children in the U.S. is often more of a problem than for adults because many government funding sources for AT are geared toward improving job placement and servicing the elderly. As noted by Enders and Hall (1990),

> Funding issues are generally the bottom line in providing technology for individuals with disabilities. We can research, develop, transfer to private sector, utilize, build, and adapt, but if money is not available, the device -- be it simple or sophisticated -- will not reach the intended user, the disabled person. (p. 461)

Finding solutions to funding barriers is a major goal of many of the state AT projects. The state projects are providing information about funding sources and providing some solutions to the funding problem. For example the Utah project has developed a Guide for Funding AT in Utah (Hammond, Jentzsch, McCarty & Fifield, 1992). Many other states are doing the same. Also in Utah, a Funding Foundation has been established, which provides a vehicle for receiving donations and administering low-cost loans to consumers for AT. Other states are developing similar programs. Progress is being made toward reducing the funding barrier; however, finding solutions to funding barriers are more complicated than finding solutions to providing training and improving awareness.

AT Leaving the Classroom

An additional problem encountered by students in the United States public education system is that AT purchased by the school system can only be used in the school. This creates a major problem for some students who need the AT both in the school and at home. Typically individual school districts set policy on the use of AT purchased by the school. Often the rules are based on practice rather than policy.

As noted earlier, it is required by law to consider AT in a child's IEP. Consequently, if AT is required to fulfill the child's IEP objectives, and if fulfillment requires using the AT to complete homework, the practice of restricting AT use to the school is illegal. Optimistically, many of these practices and policies will be revised. On the other hand, this situation may result in AT being overlooked in the IEP process. Parents and other advocates need to press for the consideration and, if necessary, purchase and appropriate use of AT in the classroom and at home.

POPULAR AT DEVICES

Advances in technology have greatly increased the potential of AT to improve functional capabilities. These advances produce AT at different levels of complexity, and AT is often characterized as low-tech, medium-tech, or high-tech. Most AT is not high-tech; in fact, there are many simple solutions to accommodating disabilities. For instance, important accommodations can be made by widening the aisles between student desks, by making desks and tables accessible, or by tying a rope to a door knob to help a student who uses a wheelchair pull a door closed. This section describes the AT devices that have been frequently used to

provide access to education for students with disabilities and provides examples of low-, medium-, and high-tech devices.

Low-Tech to High-Tech Devices

In school settings, a variety of AT devices can be used to increase potentials and capabilities of students. These devices can be organized into the three AT categories: low-tech, medium-tech, and high-tech.

Low-tech devices are simple aids that are non-electrical. An example of a popular low-tech device is a white cane used by blind students to navigate. The advantage of low-tech devices is that they are relatively inexpensive. Medium-tech devices are aids that might use electricity, but are not computer driven. An example of a medium-tech device is an electric wheelchair. It allows the student with a disability to attend school and participate in a regular education classroom. High-tech devices require computerized systems that are operated through a particular software program (Church & Glennen, 1992). One of the most popular and versatile high-tech devices is the microcomputer. The primary advantage of the microcomputer is that most schools already have access to them. The microcomputer can be used by students with speech impairments to synthesize a voice, for students with learning disabilities to receive individualized instruction, or students with mobility impairments to use a network to access places that they might not be able to reach otherwise. Table 1 lists examples of high-, medium-, and low-tech devices and their functional uses.

Table 1. Low-, Medium-, and High-Tech Devices, and Their Functional Uses.

Device Name	Communication	Mobility	Environmental Control	Education	Independent Living
Low-Tech:					
Keyboard guard	X			X	X
Head pointer	X			X	X
Typewriter	X			X	X
Picture symbols	X			X	X
White cane		X		X	X
Medium-Tech:					
Electrical wheelchair		X		X	X
Wheelchair lift		X		X	X
Hearing aid	X			X	X
Mechanical switches	X	X	X	X	
High-Tech:					
Microcomputer	X		X	X	X
Enlarged print system which uses a special monitor and software	X			X	
Speech synthesizer - such as Dectalk	X			X	X
Direct selection communication aid - such as Macaw	X			X	X
Direct selection communication aid and control - such as Eye Gaze	X		X	X	X

Access to AT

Currently thousands of AT devices are available. Because there are so many devices, it is essential that teachers and specialists know how to locate and select appropriate devices for students. If the appropriate device is chosen, it can improve a student's academic and social experiences by reducing or eliminating the disability, compensating for the disability, and/or increasing the student's abilities (Sedlak & Wisniewski, 1992). Locating an AT device can be facilitated by using Information and Referral Systems (I&R). An I&R system provides consumer and clinicians with information and referral services about AT devices and services for persons of all ages with disabilities. Based on an extensive nationwide study of I&R systems, A. Lopez-DeFede (personal communication, April 15, 1992) defined the following requirements of a fully functioning I&R system:

- Provides AT I&R as a formal service or as a central focus
- Provides AT I&R services
- Provides after-hours reception and recording arrangements
- Employs qualified I&R specialists
- Provides entry-level and in-service training for I&R specialists
- Uses a computerized system
- Uses a standard taxonomy
- Uses methods for data collection, data verification, data maintenance, and data updates
- Shares databases with other agencies
- Provides referral outside operating area
- Includes procedures for follow-up

- Publicizes its services
- Uses consumer feedback to measure effectiveness of services provided

According to A. Lopez-DeFede (personal communication, April 15, 1992), the I&R system developed and operated by the Utah Assistive Technology Program (UATP) located at Utah State University is one of two I&R systems in the nation that meet these requirements. Consequently, this system is an appropriate system to exemplify. The operators of the UATP system use computerized databases and information sources such as ABLEDATA, Used Equipment Sales and Loan Bank, Utah Cooperative Service Directory, ADA Database, SPECIAL TECH, and Access Utah Network Materials Library. The following briefly explains each database:

- ABLEDATA - contains references to 18,000 assistive devices, product descriptions, the manufacturers and/or distributors of each device, and how much each device costs.
- Utah Equipment Sales and Loan Bank - contains references to used assistive devices, product names, and the person or agency that sells the device.
- Utah Cooperative Services Directory - contains references to AT services and licensed professionals.
- ADA Database - can be searched using words or phrases searches to select specific information about ADA which can be printed or recorded on a computer disk.
- SPECIAL TECH - contains references to computer-based assistive devices.
- Access Utah Network Materials Library - contains a collection of 500 paper-based materials and 100 videotapes that are available for reference or loan.

Based on her study, Lopez-DeFede (1992) recommends a nationwide I&R system which will access multitudes of devices and services. The nationwide I&R system should address the following needs:

- require specialized services not routinely available;

•require comparative knowledge of services/programs in other states;

•transcend geographical boundaries;

•relate to consumer mobility and independence; and

•require advocacy beyond what is available within each region.

After locating the information on devices, consumers should seek out professionals to help them choose an appropriate device.

ASSESSING THE NEED FOR AT

This section describes how a person with disabilities might be assessed for AT. Assessing the need for and selecting Augmentative Communication (AC) devices is used as an example to illustrate an assessment process.

AC as an Example of AT

AC is a good focus area because of its importance in accessing education. AC also appears to be representative of other areas of AT. As with other AT devices, AC devices can be categorized according to function and complexity. Many of the procedures used to evaluate AC devices are similar to those used with other AT. For example, a team approach, which involves the consumer (user) and/or parent and relevant provider disciplines in evaluating the need for, selecting, acquiring, and maintaining AT, is consistently recommended for evaluating AC and other AT. AC is described to exemplify the range of services and procedures generally associated with AT devices.

This section begins with a general description of AC, followed by brief descriptions of AC devices, the assessment process typically used in assessing the need for AC, and the training required for the person with disabilities to use AC devices.

AC is a term used to describe: (1) supplementary techniques that enhance communication by complementing whatever vocal skills the individual may possess (Harris-Vanderheiden, 1977 and Vanderheiden, 1977) or (2) any approach designed to support, enhance, or augment the communication of individuals who are not capable of independent verbal communication in all situations (Shane & Sauer, 1986). The generic term "communication augmentation" refers to any approach designed to support, enhance, or augment the communication of individuals who are not independent, verbal communicators in all situations (Beukelman, Yorkston, & Dowden, 1985). In general, AC is a process that allows individuals to communicate more efficiently and effectively. An effective AC program is designed to enhance the quality of life for persons with speech and language impairments in accordance with each person's preference, abilities, and lifestyle [American Speech Language Hearing Association (ASHA) definition (1988)].

As noted by Shane and Sauer (1986), AC devices can be categorized as follows:

(1) Unaided communication systems. Example: Sign language allows people who have speaking or hearing disabilities to communicate through a trained interpreter. Cost varies according to the number of classes taken by the student and if the educational institution provides interpreters free of charge.

(2) Nonelectric communication aids. Example: Picture symbols allow the user to communicate needs or desires through the manipulation of pictures. A teacher can produce

picture symbols out of construction paper and magazine pictures for less than $5, or a person can buy premade picture symbols for about $20.

3) Electronic communication aids. Example: SpeechPAC is a portable synthetic voice communicator with a full-sized keyboard, a built-in printer, an LCD screen, and a built-in microcassette drive for saving and loading programs. A typical system costs about $1,000.

4) Microcomputer systems using dedicated communication software. Example 1: Cricket is a synthesizer that brings the features of the Echo+ to the Apple IIc microcomputer. It offers two separate voice modes, a vocabulary of over 700 commonly used words in a female voice as well as a large vocabulary in a synthesized voice. Cricket costs under $200. Example 2: Dectalk is a sophisticated synthesizer and will interconnect to most computers. It converts ASCII text into relatively natural speech. It offers voice options including a male, a female, and a child's voice. Dectalk, which costs over $2,000, has an extensive vocabulary and pronounces words with relative accuracy.

Assessing the Need for AC Devices

Determining the need for and selecting the appropriate AC device requires a functional assessment of the person with disabilities. The current trend in AC assessment is to use an interdisciplinary team for coordination. An interdisciplinary team assessment emphasizes the total needs of the person. When assessing a child, the family is included in the assessment process (Munson, Nordquist, & Thuma-Rew, 1987). With the interdisciplinary approach, a team of professionals in a school, hospital, or other setting work directly with the person with a disability, the family, and any other persons or agencies involved with the person to develop a comprehensive program. Munson et al. (1987) believe the interdisciplinary team approach is

the most comprehensive and effective method of providing services to persons with a communication disability. Below are two examples of interdisciplinary team assessments:

> Example 1. The Non-Verbal Assessment Program is staffed by speech and language specialists knowledgeable in assessment, etiology and behaviors of nonspeaking pupils, as well as in the field of language development and language disability, and are California licensed and ASHA certified. In addition to the speech and language specialist, the team usually includes an occupational therapist, a physical therapist, and a school psychologist who help select and individualize appropriate communication systems (Cook, 1988).

> Example 2. The interdisciplinary team model used by Shane and Sauer (1986), for assessing children with communication disabilities, is staffed by a consumer advocate, follow-through coordinator, fabrication specialist, fitting specialist (interface and electronic aid aspect), audiology specialist, biomedical engineer, component manual signer, educator, physician, occupational therapist, parent/caregiver, physical therapist, psychologist, social worker, and speech-language pathologist.

In addition to the interdisciplinary team approach there are also the multidisciplinary and transdisciplinary approaches to evaluating a person with a communication disability. In the multidisciplinary approach, a range of professionals serve a given child, but generally work individually in providing evaluation and management. The transdisciplinary approach is often favored by professionals working in residential settings. As with the multidisciplinary team approach, several professionals may evaluate the person and contribute to planning the program. However, one professional usually is responsible for being the primary therapist rather than sharing the responsibility. Both the multidisciplinary and transdisciplinary approach may include a physical therapist, speech pathologist, occupational therapist, physician or nurse, social worker, pedodontics, audiologist, psychologist, nutritionist, and educator as part of the team (Munson et al. 1987).

With any of the models, a methodical step-by-step process is used. When assessing a nonspeaking person for an AC system, Young and others (1985) recommended assessing the following:

- physical abilities, which include optimal control of posture, seating abilities, and positioning;
- intellectual abilities, which include determination of learning style and continual appraisal of the individuals cognitive status;
- sensory abilities, which include determination of visual status, auditory status, and tactile/kinesthetic status;
- communication needs, which include determination of the need for an AC system to enhance conversation and writing abilities; and
- environmental concerns, which include where the individual resides, attends school, works, and socializes.

Vanderheiden (1984) suggests a number of points which should be considered when determining the need for and selection of a device:

- The focus of the entire communication development program should be on interaction rather than on the device.
- Purchasing a high-tech device may advance immediate communication, but it can block future potential by making the person dependent on the device and thereby reducing the need to develop natural communication abilities.
- When considering a student's communication needs, it is important to address both conversation and writing needs.
- Speed is crucial, both in conversation and in writing.

Training to Use AC Devices

After selecting a device, training is often required to effectively use the device. Typically, both the professional and the client require training to use the AC device effectively.

Some devices are simple to use and can be operated by following the instructions provided with the device. In other cases, as noted by Cavalier (1992), effective training strategies are essential to the operation of a device. He believes that the development of effective training strategies is equally as important as the device itself. Often, effective training is overlooked in research and development of AT in special education. In addition, few educators who work with learners with disabilities have received training on the use of adaptations and devices (Brooks & Redden, 1986). Thus the device is often abandoned when a malfunction occurs, when a student is unable to use the device without training, or when student improvement related to the device cannot be measured (Garner & Campbell, 1987). As noted by Phillips and Zhao (1993), the training process may indicate device inadequacies. Consequently, training increases the likelihood of receiving the appropriate device, thus reducing abandonment. When training occurs, it is often initiated by the professional. Cottier (personal communication, July 1993), a speech-language pathologist at the Non-Verbal Assessment Center, notes that she initiates most of her training on utilization of a specific device from the manufacturers at workshops or conferences. In addition, she states that clients receive their training about 80% of the time from a speech pathologist and about 20% from an occupational therapist.

As noted earlier, this section on AC was provided as an example of how a person with a disability might be evaluated for, acquire and be trained to use AC devices. The next section contains a synthesis of information about general AT device evaluations and characteristics. Most device types are included in the synthesis, but much of the device information pertains to AC devices.

CHARACTERISTICS OF EFFECTIVE AT DEVICES

This section is a synthesis of information from 29 articles, which describe evaluations of AT devices. The section begins with a description of the target population used in the synthesis followed by a summary of the 29 articles, a synthesis of the summarized articles, and the limitations of the synthesis.

Target Population for Synthesis

Potentially, all persons with disabilities may benefit from the use of AT, which covers a wide range of technologies. This report, however, is limited to the use of AT in the education of school-age children. The report applies to any student who has a disability that may impair learning or access to education. The report is limited to AT, as contrasted to learning technologies because NCITE has commissioned other research syntheses on learning technologies. Also, because similar research syntheses about hearing and vision have been commissioned by NCITE staff, this synthesis did not involve AT used by persons who have hearing and vision impairments.

Summary of Articles

As mentioned earlier, the major purpose of this report is to identify AT device characteristics that may help identify quality devices. The reader is reminded, however, of Vanderheiden's (1984), caution that the focus of a device evaluation should be on the interaction between the user and the device and not just on the device. Enders and Hall (1990) also note that the equipment is not in itself important, the assessment needs to determine relative contribution to functional goals, and Galvin (1989) claims that the ultimate test of the

effectiveness of a device is how well it fits the user. Further, Kohn, Mortola, and LeBlanc (1991) strongly recommend a tracking system to provide follow-up information on device effectiveness. Obviously, it is difficult to make predictions about how well a device will function based on device characteristics alone. The entire evaluation and follow-up assessment is important. However, consensus about device characteristics that are indicators of quality may assist manufacturers in the design and development of AT and may help consumers and service providers select AT.

In order to determine consensus among experts about effective device characteristics, a review of the literature was conducted. Over 100 articles that dealt with AT devices were reviewed. Twenty-nine articles contained relevant information and were selected for further review. An article was selected if the authors described an evaluation used for selecting AT devices, and if they included recommendations about device characteristics as a result of their evaluation. Information from the 29 articles was summarized and is presented in Table 2.

Table 2 is divided into four columns containing (a) bibliographic information, a brief description of the article, and the type of device evaluated; (b) the evaluation method and criteria used to conduct an evaluation or in some cases used to directly evaluate devices; (c) who was involved in the evaluation; and (d) the device characteristics identified from the evaluation. Primarily, Table 2 provides information about frequently used evaluation procedures and recommended device characteristics. The section, immediately following Table 2, provides an interpretation of the information in Table 2. Table 2 is extensive and the reader is encouraged to peruse the table, read the interpretation, and then refer back to Table 2 for additional

information. The following describes the information in each of the four columns of Table 2 along with a brief description of the findings for each column.

Article Descriptions (Table 2, Column 1)

Complete bibliographic information for each article is provided in the References section. The descriptions provided in this column of Table 2 are brief and included mainly to identify the type of article. Information about the type of device is also included. Of the 29 articles summarized in Table 2, 14 dealt with general devices, 6 with mobility devices, 2 with computer access devices, and 7 with AC devices.

Evaluation Methods and Criteria (Table 2, Column 2)

The evaluation method describes the type of evaluation conducted. Evaluation methods were divided into the following four categories:

1. Research--Research included comparative research and survey research. Comparative research involved a formal research design used to define the structure of comparisons of devices or to determine the function of a device over time and across users. Survey research involved opinion data about devices from consumers collected through telephone interviews, questionnaires, or focus groups.
2. Clinical Trials--Clinical trials were based on observations of persons with disabilities using devices in their usual settings such as home, work, school or recreation. Clinical trials can be both short or long-term. Short-term could be in-house observations or side-by-side trials in which one user tries several

devices. Short-term does not provide information about durability and safety over time, which can be provided by more expensive, long-term observations.

3. Engineering Analysis--Products were tested in laboratories independent of the user. Tests were designed to determine how well a device will function during actual use. In many cases products were tested to extreme limits in laboratory simulation of use and potential misuse (Barnicle, 1991).

4. Expert Opinion--The method of selection or evaluation was not clearly defined and the set of criteria used was typically the result of a clinician's opinion. As noted by Barnicle (1991), "the decision of which device is best is often based on a clinician's past experience with previous patients and products, or the contents of a sales pitch or sales literature" (p. 44). In addition to direct experience, the clinician's opinion may be based on research informally reviewed but not reported in the article. Expert opinion may also be based on clinical trials that were not identified. Considering the paucity of research concerning quality of AT devices, the opinions of clinical experts may be the best current determinant AT device quality. However, almost exclusively, expert opinion has been derived from a consumers opinion.

Of the 29 articles summarized, 8 were derived from research findings, 3 from clinical trials findings, 4 from engineering analysis findings, and 16 from expert opinion. (One article reported using both Engineering Analysis and Expert Opinion; another article reported both Clinical Trials and Expert Opinion.) Only one of the research studies used a controlled

experiment to determine findings. Findings from the other six studies were based on consumer opinion gathered through questionnaires, telephone surveys, and group consensus technique.

The evaluation criteria consists primarily of the criteria used to make a selection. Enders and Hall (1990) recommend using 24 criteria (see Table 2, Enders and Hall, 1990) for evaluation. These 24 criteria comprise the most comprehensive set of evaluation criteria and lead to the questions asked or information collected in making AT selections. Additionally, there are specific criteria for specific devices such as water spray tests for automatic lifts (see Table 2, VA Standard Design). Referring to Table 2, other general criteria that may be added to the Enders and Hall (1990) list include safety, speed of operation, and fatigue to person.

In many cases, a device characteristic has the same name as a criterion used in the AT evaluation. In those cases, the criterion is also listed as a device characteristic. In a number of cases, criteria given different names by different authors are summarized under one characteristic. For example, maneuverability, stability, range, and handling are summarized under operability. Also listed under evaluation criteria are general criteria that should be considered when doing an evaluation. One of the general criterion used frequently is that technology must be matched to user needs. Another criteria frequently mentioned is that the consumer (user) must be part of the evaluation. Often a criterion does not directly relate to characteristics of AT devices. The criterion is included, however, to help provide a general guide on how to conduct an evaluation, how the characteristics of quality devices are derived, and the questions consumers and clinicians ask when evaluating, selecting, and purchasing assistive devices.

Who Performed or Should Perform Evaluations (Table 2, Column 3)

If the article described a research study or engineering analysis, information in this column describes who conducted the evaluation and if the evaluation is based on provider or consumer survey opinion; otherwise, this column identifies the recommendation of the author(s) as to who should be involved in an evaluation. Essentially all of the articles describing AT selection, recommended the use of an interdisciplinary or multidisciplinary team. The list contained in Barnicle (1993) is representative of the disciplines commonly mentioned and would be comprehensive with the addition of a physician and rehabilitation engineer. Appendix A contains a list of all disciplines mentioned and the number of times mentioned in the 29 articles. In 20 of the 29 articles, the consumer and/or a family member was considered an essential team member in the evaluation. Most authors consider consumer input essential. All but one of the research studies was based on consumer opinion. One of the research studies involved observations of consumers.

Characteristics of Quality AT Devices (Table 2, Column 4)

This column contains lists of characteristics of devices that have either been identified through research, clinical trials, engineering analysis or expert opinion. With the exception of the Batavia and Hammer (1990) entry, the lists are not prioritized as to importance. Additional information and interpretation of the information in this column is presented in the section, Synthesis of Device Characteristics.

Table 2. Summary of Evaluation Process and Recommendations of Device Characteristics

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Angelo, Deterding, & Weisman, 1992 *Comparing Three Head-Pointing Systems Using a Single Subject Design* Description: Research report describing a comparison of three types of head control devices. Device Type: Computer Access	Method: Research -- Used a single-subject research design to compare three head point systems with nine subjects. Typing speed and accuracy were dependent variables. Criteria: Typing speed Typing accuracy	Consumers: Consumers evaluated appearance and ease of use. Researchers: Researchers were Occupational Therapists.	Computer Access: • Typing speed • Typing accuracy General: • Appearance • Ease of use
Barnicle, 1991 *Evaluating Assistive Devices: What You Need to Know* Description: This is a descriptive report, describing the need for independent AT evaluations using an interdisciplinary approach. Specific evaluations are not documented. Device Type: General	Method: Expert Opinion -- Recommend using a combination of clinical trials and engineering analysis. Criteria: Author recommends the following: • Measurements of performance (size, weight, weight capacity, power requirements) are designed to determine function during actual use. • Safety (electrical, mechanical, and operational) - a clinical analysis of the safety of a device will point out situations where a normally safe device may be inappropriate for a specific individual. • Ease of use (human factors of a product) the human factor analyses show suitable ability for individuals with certain limitations. • Required maintenance of a device is also an important factor.	Consumers: Author states "It is essential to receive feedback from the consumer. Follow-up quality evaluation by disabled clients of both service delivery and of assistive technology in use has often been recommended but is only beginning to be used by those who provide devices." Interdisciplinary Team: Author recommends using: The team should include occupational therapist, physical therapist, vocational rehabilitation specialist, speech-language pathologist, therapeutic recreation specialist, social worker, nurse, teachers, engineers, manufacturers, and vendors.	General: • Electrical safety • Mechanical safety • Operational safety • Ease of use • Maintenance Requirements

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Barnicle, 1993 *Evaluating Assistive Devices: What You Need to Know* Description: Describes the process and criteria used for product evaluation by the Request Project, National Rehabilitation Hospital. Device Type: Mobility	Method: Expert Opinion and Engineering Analysis – Proposed method designed to measure performance, safety and ease of use. Criteria: Performance criteria dependent on product (e.g., canes, walkers, etc.) • Static loading • Dynamic loading • Slip resistance • Stability • Quality of construction and design Scooters • Maneuverability • Stability • Range • Handling Batteries • Capacity • Lifetime Safety criteria include: • Electrical • Mechanical • Operational • Compatible with other devices Ease of use criteria involves human factors analysis such as fit with a person's abilities. Availability of service and environmental fit are also criteria.	Consumers: Feedback from consumers is necessary. Providers: Requires interdisciplinary approach including: • Occupational therapists • Physical therapists • Vocational rehabilitation specialists • Speech language pathologists • Therapeutic recreation specialists • Social workers • Nurses • Teachers	• Field-test data • FDA approval • Cost • Repair record • Warranty • Maintenance requirement • Portability

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Batavia & Hammer, 1990 *Toward the Development of Consumer Criteria for Evaluating Assistive Devices* Description: Describes an evaluation of device characteristics using a delphi study with two groups of consumers. Device Type: General	Method: Research -- A delphi method was used with two groups of consumers who identified and prioritized evaluation criteria. Criteria: The twelve criteria used in the evaluation are listed and explained in Table 4.	Consumers: Evaluations based on consumer opinion.	Ranked by Importance: 1. Effectiveness 2. Affordability 3. Operability 4. Dependability 5. Portability 6. Durability 7. Compatibility 8. Flexibility 9. Ease of Maintenance 10. Securability 11. Learnability 12. Personal Acceptability 13. Physical Comfort 14. Supplier Repairability 15. Physical Security 16. Consumer Repairability 17. Ease of Assembly
Brooks & Hoyer, 1989 Consumer Evaluation of Assistive Devices *Consumer Evaluation of Assistive Technology* Description: Describes research to help determine if there were differences between two groups of consumers and how they evaluate AT devices. The two groups consisted of those primarily interested in AT for employment and those primarily interested in independent living. Device Type: General	Method: Research -- Matched samples of adults with disabilities responded to oral questionnaire.	Consumers: Consumers responded to oral questionnaire. Researchers: Administered oral questionnaire.	Differences between groups not statistically significant, although preferences were shown. Employment: • Durable • Looks good • Made user proud • Worked well with other devices (compatibility) • Sturdy Independent Living Interest: • Convenience • Comfort • East of use (simplicity) • Sturdy

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Brown & Lavanchy, 1990 *Evaluation of Rehabilitation Devices: A Practical Example* Description: The article outlines in depth the evaluation process that a project officer goes through to assess a rehabilitation device. Device Type: General	Method: Expert Opinion. Types of Evaluations: • Five formal in-house reviews • Two rounds of reviews by clinical experts • Final review by the participating manufacturers		
Holder-Brown & Parette, 1992 *Children with Disabilities Who Use AT: Ethical Consideration* Description: Descriptive report describing selection considerations for selecting AT. Device Type: General	Method: Expert Opinion.	Consumers: Children and families should be actively involved in choosing and evaluating technology to ensure dignity of choice. Providers: Multi-disciplinary Team: 1. OT 2. PT 3. Speech Pathologist 4. Nurse 5. Teachers 6. Parents	• Sufficiently portable to move from school to home to school easily • Ease of training • Reasonable maintenance • Compatible with practical constraints such as instruction time required

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Burnette, 1992 *Government Sponsored Special Education Projects: Considerations for Designing Assistive Devices* Description: Descriptive report describing the legislative mandates of legislation (IDEA) and the emphasis on AT design principles of the US Office of Special Education Programs (OSEP). Contains a review of OSEP projects relating to the provision of AT. Device Type: General	Method: Expert Opinion. OSEP project directors opinions about design principles and selection of AT. Criteria: A general criteria are innovations that are compatible with the values, experiences, and needs of the user are more likely to be adopted: • Technology must be matched to user needs • Use engineering analysis to determine and evaluate design such as the physical attributes of the system • Use clinical trials to evaluate the performances of AT in actual use	Consumers: Parents and students should be part of the selection team. Providers: In addition to parents and students, the selection team should include teachers, counselors, therapists, physicians, and social workers.	• Portability • Ease of use • Availability • Flexibility • Compatibility • Availability of Training • Safety

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Buzolich, 1988 *Procuring Short-term Loan of Equipment for Field Testing in J. Kirstein and Nathaniel A. Peters Establishing an Equipment Library* Description: Description of how clinicians, teachers, and students who use aids (and their families) are asked to fill out an evaluation form. This provides the center staff with information, not only about the performance of a particular aid with particular clients, but also with data about the performance of a particular aid over time with multiple clients. Device Type: Augmentative Communication	Method: Clinical Trials -- User completes evaluation forms to evaluate communication aids. Criteria: American Speech Language Hearing Association: 8 steps to field testing AT devices: 1. Develop specific goals 2. Customize the communication device 3. Provide frequent, direct training for student during field testing program - approx. 2 hours/week 4. Train family members and school staff 5. Record student performance using an observational checklist 6. After training, review notes or videotape with team 7. Make a final decision on the device 8. Return device to the manufacturer or loan equipment library	Consumers: Student users and family members complete form. Providers: Clinicians and teachers also complete form.	• Portability • Complexity • Comprehensibility • Do materials explain ALL aspects of the aid's functions? • Pupil Flexibility • Classroom Flexibility • Initial Instructional Value • Sustained Motivational Value • Reliability • Durability • Incidental Stimulus Value

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Carlson, 1988 *Chapter 6: Evaluating the Need for Augmentative Communication* Description: Descriptive report describing a process for evaluating the need for augmentative communication. Device Type: Augmentative Communication	Method: Expert Opinion -- Primarily concerned with the evaluation of need, not of devices.	Not specified.	• Training necessary • Will not be used if too complex
Cook and Barker, 1982 In Coleman (Ed.) A systematic approach to choosing interfaces for assistive devices. *Enhancing the Educational Potential of Non-Oral Children through Matching Communication Device Capabilities to Children's Needs* Description: The report describes activities and results of a project to identify communication characteristics that would help match appropriate communication devices to non-oral children. Device Type: Augmentative Communication	Method: Expert Opinion -- Employs a systematic evaluation process (technical evaluations, human factor evaluations, and clinical trials) for identifying user needs and abilities and uses comparative testing of interfaces to match device to user. Quantitative Evaluation: • Speed of Response - time between person's rest position to successful activation of the interface • Accuracy of Response - measuring the number and types of errors a person makes when using an interface • Fatigue of Person - the degree that an interface causes fatigue • Repeatability - the degree of performance maintained over time Clinician's Criteria: • How well does the device perform when used by clients? • What is the level of the manufacturer's responsiveness to repair needs and suggestions for improvements.	The clinician performs the evaluations. During or after the evaluation the consumer is asked to give feedback on the device and procedures.	• Ergonomics (Interface with user) • Reliability • Physical Comfort • Accuracy • Operability

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Enders & Hall, 1990 *Chapter 4: Evaluating the Technology* RESNA Sourcebook Description: This chapter describes a rationale and process for evaluating hardware. A majority of the selection criteria is from Guthrie (1984), Evaluating Aids for Disabled People. The evaluation process is adopted from work done by the Southwest Research Institute's Rehab-Engineering Center and work done by Cohen and Frumkin. Device Type: General	Method: Expert Opinion -- Recommends the following types of evaluations: • Technical: physical attributes • Functional: how well the device does what it was built to do • Comparative: functional characteristics relative to other similar products • Purchaser: all the other types of evaluations, plus economic and emotional issues Consumer Criteria: Consumers shopping for AT should consider the following: • Will it solve the problem? • Can you get promises in writing? • What services are available? Are the services reliable? • What kind of technical support is available for solving interface problems? • What kind of training is available and how much does it cost?	Both the consumer and clinicians should conduct the evaluations. Frequently, the professional judgement of a physician, therapist, prosthetist, or engineer should be sought when a consumer is considering a new device.	• Convenience • Aesthetics • Adjustability • Compatibility - social environment • Compatibility - user • Ease of Use • Reliability • Durability • Safety • Availability • Service and Repair

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Enders & Hall, 1990 (continued)	<u>Consumer and Clinician's Criteria:</u> • Performance - How effectively and efficiently does this product perform? • Convenience (Ergonomic factors) - Is the product generally convenient? • Acceptability - Is the product acceptable to users in its appearance, general suitability, and compatibility with the social environment where is used? • Adjustability - How easy is it to adjust the product to fit the user or alter its performance? • Ease of Use - Is the product easy to use or does it require excessive strength or over-exertion? • Dimensional Compatibility (or anthropometric fit) - Is the product compatible with the anatomical and anthropometric dimensions, and with the physical constraints of the environment in which it is used? • Reliability - Is the product likely to stand up well to normal use or misuse? • Robustness (or durability) - Can the product withstand fairly hard use and misuse? • Cost - Is it in the price range of the consumer? • Availability - Is the product easily available? • Service and repair - What facilities for service and repairing are there?		

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Enders & Hall, 1990 (continued)	<u>Consumer and Clinician's Criteria:</u> • Functional Utility - What does the device really do? • Level of Technology - How complicated is the device? • Competition - Is the device pretty similar to something already used? • Clinical Base - How is the device prescribed, or is a prescription necessary? • Peer Approval - Who else is already using the device? • Formal Evaluation - What sort of evaluation has the device seen? • Distribution - Where is the device being sold? Who sells it? • Maintenance - Who's in charge of maintenance and services?		

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Galvin, 1989 *"Evaluation of Assistive Technology at the Rehab. Engineering Center", Natl. Rehab. Hospital Study* Description: Report of General REC evaluation procedures and the results of a preliminary telephone survey of consumers. Device Type: General	Method: Research – Telephone survey. Criteria: • Performance - does it work efficiently and effectively • Ergonomics - does it fit the individual, is it convenient to use • Reliability - does it stand up well to normal use, durable • Safety - is if safe to use • Practical Questions - cost, availability, are repair and maintenance services available (Enders & Hall) Technical Evaluation • Dimensions • Weight • Performance • Safety Tolerance Functional Evaluation • Does it meet the goals and objectives for the device? Comparative Evaluation • How does the device match up to other similar devices? User Perception Evaluation • Does the device work in real situations? • Does it fir economic and emotional issues of the user?	General REC Evaluation: REC is evaluating devices. It does not mention who at REC is doing the actual evaluation. Telephone Survey: Eighty of 250 consumers interviewed.	General REC Evaluations: • Performance • Ergonomics • Reliability • Safety • Practical Questions Telephone Survey: Preliminary Results of 80 respondents – causes of abandonment. • Servicing and repair hard to get • Not easy to use • Cost of servicing to high • Reliability not good • Requires undo assistance from another person

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Galvin, Barnicle, Phillips, & Perr, 1993 *How to Evaluate and Select Appropriate Assistive Technology* Description: Report describing steps for selecting AT devices from accessing the client to accessing the manufacturer. Device Type: General	Method: Clinical Trials and Expert Opinion. Criteria: • Task to be accomplished a. steps required b. skills needed to complete c. potential for changing the task • Consumer' Functional Abilities a. disability b. motor c. cognitive d. communication e. sensory • Consumer's Personal Characteristics a. psychosocial b. family and social support • Environment a. environmental compatibility b. resource available c. service delivery system • Device a. performance b. ease to use c. aesthetics d. cost e. convenience f. flexibility	Consumers: One criterion for selection is consumer trials.	• Maintenance and repair requirements • Lifetime cost • Aesthetics acceptable • Interface with other equipment • Convenient to use • How easy is the device to learn to use?

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Grady, Kovach, Lange, & Shannon, 1991 *Promoting Choices in Selection of AT Devices* Description: Descriptive report describing a process for making client/family centered, interest-based evaluation of the need for and selection of AT. Device Type: General	Method: Expert Opinion. The evaluation should: • Separate people from problem • Focus on interests rather than problems • Invent options for mutual gains • Insist on objective criteria Criteria: • User age • Physical capabilities • User input • User interests, likes and dislikes • User short and long term goals • Method of control - direct, etc. • Applications - educational, vocational, etc. • Expandability - for future needs • User cognitive abilities • Reliability/durability - warranties • User sensory deficits • Interfaces needed • Architectural barriers • Funding parameters/restrictions	Consumers: Consumer should be part of evaluation team. Providers: Use an AT Evaluation Team. Team is interdisciplinary including user/family, OT, PT, Speech & Language Pathologist, Rehab Engineer, Learning Specialist and Parent Consultant. Note: "Choices about selection of AT devices are best made by people who will use device. Traditionally medical model is used, which encourages selection on professional belief and not consensus involving user."	• Expandability • Reliability • Warranty • Flexibility

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Kohn, Mortola, & LeBlanc, 1991 *Clinical Trials and Quality Control* Description: Descriptive report and documentation of four evaluations. Device Type: General	Method: Clinical Trials – Clinical trials and a tracking system were used in evaluation of eyebrow switches, modular wheelchair inserts system and manually propelled stander. Criteria: Authors have developed: 1. Tracking System 2. Follow-Up Plan 3. Review Process Product provider (objective) assesses – • durability • safety • function User (subjective) assesses – • appearance • function • repair needs	Consumers: Parents completed questionnaires, and they provided subjective assessments about devices such as device appearance. Providers: • Occupation therapists • Teachers	• Durability • Safety • Appearance • Repair Needs

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Nietupski, Rathe, & Hamre-Nietupski, 1986 *Letting the Data do the Talking: Selecting the Appropriate Nonverbal Communication System for Severely Handicapped Students* Description: The article provides guidelines for using student characteristics and performance data to objectively select the nonverbal system best suited for each student. Device Type: Augmentative Communication	Method: Expert Opinion. Procedural Steps in Conducting an Alternate Treatment Design Program: • Step 1 - Conduct baseline trials • Step 2 - Institute daily training on devices and graph daily performance • Step 3 - Analyze data to determine student's performance	Consumers: Students provide feedback to teachers on performance of device. Providers: Teachers use procedural steps to select AT devices.	• Learnability • Portability • Training required
Parette, Hourcade, & Van Biervliet, 1993 *Selecting Appropriate Technology for Children with Disabilities* Description: Describes a recommended process for using a multi-disciplinary IEP team to select AT. Device Type: General	Method: Expert Opinion. Criteria: Recommends following criteria for selection: • Responds to clearly defined goals. • Compatible with practical constraints. • Results in desired outcomes. • Must match student characteristics.	Consumers: Recommends parent and student selection involvement and feedback. Providers: Recommends multi-disciplinary IEP team including: • Regular teacher • Special Ed. teacher • Occupational therapist • Speech/language therapist	• Availability • Modifiability • Simplicity of operation • Initial cost • Operation cost • Adaptability • Reliability • Repair records • Does device automatically provide student performance data

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Phillips, 1992 *Technology Abandonment from the Consumer Point of View* Description: The article provides research and studies done on why assistive technology devices are abandoned. The research and studies were done by Request, Connecticut Rehabilitation Engineering Center, Electronic Industries Foundations, and the National Survey on the Abandonment of Technology. Device Type: General	Method: Research -- Focus group observations and telephone survey of AT users. Consumer Criteria: • How well will the device enhance your performance capabilities? How will it improve your living situation? • How easy is the device to use? Is it well-designed? • How easy is the device to take care of? How much can you do yourself? • How affordable is the device to purchase, install, maintain, and repair/ • How reliable is the device? How often will it break down. • How safe is the device? What safety features does it have? • How durable is the device? How long will it last? • How comfortable and attractive is the device?	Clinicians evaluated the consumers who participated in the focus groups. Consumers evaluated the AT devices in the telephone survey.	Characteristics included in Batavia & Hammer (1990).

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Phillips & Zhao, 1993 *Predictors of Assistive Technology Abandonment* Description: This article reports on research that was conducted at the Rehabilitation Engineering Center. The research focused on finding out why people who use assistive technology devices abandon the device. Device Type: General	Method: Telephone interview surveys and written surveys. Criteria: A 30 item questionnaire was completed by 227 AT using consumers. Only items pertaining to AT characteristics are listed here. Yes, No, or Not Applicable were possible answers. • Do you feel that it was inexpensive to purchase? • Was it easy to obtain from the supplier? • Did the installation/assembly require a lot of work? • Did you require more than two hours of training in its use? • Is/was it easy to make it work? • Do you require assistance in using the device? • Did/does the item always work • Was/is it attractive? • Was/is the item comfortable? • Was/is the item safe to use? • Was/is it easily transportable? • Was/is it easily stored? • Was/is it easy to get repaired?	Consumers completed the evaluation.	• Reliability • Comfort • Ease of use • Safety • Durability • Training availability • Cost • Availability

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Scherer & McKee, 1992b *Early Validity and Reliability Data for Two Instruments Assessing the Predisposition People have towards Technology Use* Description: Describes the development of an instrument (ATD-PA) to determine predispositions people have toward use and nonuse of AT. Preliminary findings are categorized by general, personality, and technology influences. Device Type: General	Method: Research -- Instrument addresses the personality and psychosocial aspects of using AT. A self-report checklist was completed by persons with disabilities. Research compared users and nonusers of assistive listening devices.	Consumers: Twenty respondents with hearing loss completed the ATD-PA with regard to assistive hearing devices.	Derived from a list of reasons of why AT is used or not used: • Compatibility • Appearance • Safety • Reliability • Ease of use • Portability • Easy to maintain • Affordability • Availability
Shell, Horn, & Severs, 1989 *Computer-Based Compensatory Augmentative Communication Technology for Physical Disabled Visually Impaired, and Speech Impaired Students* Description: Descriptive report of augmentative communication systems and use. Device Type: Augmentative Communication	Method: Expert Opinion.	Consumers: Evaluations should be conducted by specialists with student input.	• Training must be available

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Torntsky & Klien, 1982 *Government Sponsored Special Education Projects* Description: Report of a meta-analysis that identified three principles for evaluating AT: compatibility, relative advantage, and complexity. Device Type: General	Method: Research – Used meta-analysis literature review to identify principles related to the use of AT. Criteria: Compatibility – compatible with values, experiences, and needs of user. Advantage – the degree to which one innovation is perceived as being better than the idea it supersedes. Complexity – if innovation or device is too complicated or difficult to understand, it is less likely to be adopted.	Researchers: Researchers conducted a meta-analysis.	• Easy to understand • Obvious improvements over predecessor devices
Trefler, 1988 *Positioning, Concepts and Technology* Description: Descriptive article describing the process of positioning for children with disabilities who have low muscle tone. Device Type: Mobility	Method: Expert Opinion – Evaluation involves observation by team member. Criteria: • Long-term effectiveness • Works lying down and seated • Enhances abilities	Consumer: Parents part of evaluation team. Providers: • OT and/or PT trained in positioning • Physician • Technician or Engineer • Medical Equipment Dealer	• Compatibility • Adjustability • Durability • Maintenance • Affordability

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Veterans Administration Hospital, 1978a *Program Guide and Prosthetic and Sensory Aid Service* Description: This report was developed by an engineering team which created minimum safety and quality standards. Device Type: Mobility	Method: Expert's Opinion. Criteria: An adaptive automotive driving aid must pass the following standards: • Federal Motor Vehicle Safety Standards • Society of Automotive Engineers Standards • Veterans Administration Standards - Standards: • strength of materials • resistance to corrosion • fasteners • electrical components and wiring • sharp edges and projections • conventional use of motor vehicle • neutral position of control system • mode of operation • restriction of accelerator motion for mechanically linked hand controls • installation of adaptive equipment to passenger automobiles • certified installation • safety features on automotive steering	• Technical Staff	

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Veterans Administration Hospital, 1981 *Veterans Administration Standards for Electrically Powered Wheelchairs* Description: This document explains standards for electrically powered wheelchairs set by the Veterans Administration. Device Type: Mobility	Method: Engineering Analysis. Laboratory tests are performed with motors, controls, and batteries mounted in their normal position. If the wheelchair passed the laboratory test, the evaluators complete a field-test. Criteria: The wheelchair must pass the following standards: • performance - this category covers speed, incline surfaces, range, dynamic characteristics, level braking, ramp and braking standards. • electrical characteristics and requirements - this category covers level ground, ramp ascent, quiescent-energy drain, electrical energy conductance, and rain operation standards. • power drive - this category covers disengagement and types and appropriate safeguards standards • stability - this category covers occupant stability, wheelies, turning on ramps, caster-wheel flutter, tracking, and obstacles and ground clearance standards. • structural requirements - this category includes foldability, portability, and battery security and accessibility.	• Technical Staff	• Operability • Safety • Portability • Durability

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Veterans Administration Hospital, 1977 *VA Standard Design and Test Criteria for Safety and Quality of Automatic Wheelchair Lift Systems for Passenger Motor Vehicles* Description: This document states standards developed by the Veterans Administration to present desired qualities and features of lifts and to specify those attributes necessary to control quality, safety, and performance of the item. Device Type: Mobility	Method: Engineering Analysis. Criteria: Lift must pass the following test: • receiving inspection test • dimensional test • water spray test • electrical current test • weldment test • platform opening test • finish coating test • control inspection test • acceleration test • slop dimension test • visual inspection • occupant hazards test • platform opening test • operational safety test • wheelchair retaining test • maintainability • accelerated lift cycle test • general electrical test • chain drive test • hydraulic components test • wire rope test • fastener test and inspection • power screw test • static load test	• Technical Staff	• Durability • Maintainability • Safety

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Veterans Administration Hospital 1978b *VA Standards Design and Test Criteria for Safety and Quality of Special Automotive Driving Aids for Standard Passenger Automobiles* Description: This document discusses the Veterans Administration utilization of three sets of standards to evaluate an adaptive automotive driving aid. Device Type: Mobility	Method: Engineering Analysis. Criteria: An adaptive automotive driving aid must pass the following standards: • Federal Motor Vehicle Safety Standards • Society of Automotive Engineers Standards • Veterans Administration Standards - Standards: • strength of materials • resistance to corrosion • fasteners electrical components and wiring • sharp edges and projections • conventional use of motor vehicle • neutral position of control system • mode of operation • restriction of accelerator motion for mechanically linked hand controls • installation of adaptive equipment to passenger automobiles • certified installation • safety features on automotive steering	• Technical Staff	• Safety • Durability

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Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Veterans Administration Hospital, (continued)	Method: Each device undergoes three types of test: • static testing - applies force to the device to simulate actuation of the fully assembled adaptive control system. • fatigue life cycle - uses a combination axial and torsional testing machine to determine durability • resistance to vibration testing - applies force to the handle of the control lever of a completely assembled adaptive automotive hand control system.		

Table 2. Continued

1 Source/Description	2 Evaluation Methods and Evaluation Criteria	3 Who Performed or Who Should Perform Evaluations	4 Characteristics of Quality AT Devices
Young & Anderson, 1985 *Guidelines for Purchase of Services and Assistive Devices for Individuals with Communication Disorders* Description: The article gives guidelines for purchasing communication devices which were created by speech-language pathologist and audiologist. Device Type: Augmentative Communication	Method: Expert Opinion. Types of Evaluations: • Physical - optimal control of postural tone, optimal seating and/or positioning, and utilization of most versatile motor skill for operating an augmentative system • Intellectual - continuing appraisal of the individuals's cognitive status and determination of learning style • Linguistic - determination of language comprehension, expressive language, appropriate symbol set or system, individual's use of pragmatic in communication, and assessment of communication intent • Sensory - determination of visual, auditory, and tactile/kinesthetic status • Communication Needs - determination of need for augmentative communication system to enhance conversation, writing and signaling emergency, basic care, and related issues. • Environment - where the individual resides, attends school, works, and socializes.	Depending upon the needs of the consumer, the interdisciplinary team may include any or all of the following: • consumer • speech-language pathologist • audiologist • physical therapist • occupational therapist • educators • physician • psychologist • seating and fitting specialist • engineer • social worker • vocational counselor • vendors • extended family • friends • primary caregivers	• Portability • Training Needed • Flexibility • Operability

Synthesis of Device Characteristics

The following synthesis is derived from information contained in Table 2. The information from column 4 (Characteristics of Quality AT Devices) of Table 2 is summarized in Table 3. The frequencies in Table 3 show the number of articles in Table 2 in which a particular device characteristic is listed. Column 6 in Table 3 labeled Total Frequency is the sum of the frequencies of the other four columns. The list of device characteristics in column 1 of Table 3 are from the Batavia and Hammer (1990) study (see Table 2). The Batavia and Hammer list was used to establish a base line of device characteristics for three reasons: (1) it was empirically derived, (2) characteristics were ranked by importance, and (3) it appears to be the most comprehensive list identified in the current review. Brief descriptions of each characteristic in the list are contained in Appendix A.

The following analysis is based on the assumption that frequency of occurrence is an indicator of importance. Based on this assumption, the total frequencies in column 6 of Table 3 were ranked, with the highest frequency being ranked first. This ranking of total frequencies, along with an average of the Batavia and Hammer and the total ranks, are contained in Table 4. Concurrent validity for this assumption was provided by determining the relationship between the Batavia and Hammer ranking and the total ranking.

Table 3. Frequency of Occurrences of Characteristic from Column 4 of Table 2

DEVICE CHARACTERISTICS	FREQUENCY OF OCCURRENCES				
(1) Characteristics Identified by Batavia and Hammer, 1990	(2) From Research Findings	(3) From Clinical Trials Finding	(4) From Engineering Analysis Findings	(5) From Expert Opinion	(6) Total Frequency (sum of columns 2-5)
1. Effectiveness	3	1			4
2. Affordability	4			6	10
3. Operability	7	2	1	9	19
4. Dependability	7			6	13
5. Portability	2	1	1	5	9
6. Durability	5	2	2	2	11
7. Compatibility	3	1		2	6
8. Flexibility	1	1		9	11
9. Ease of Maintenance	4	2	1	4	11
10. Securability	1				1
11. Learnability	3	3		3	9
12. Personal Acceptability	5	2		2	9
13. Physical Comfort	5			2	7
14. Supplier Repairability	1			3	4
15. Physical Security	5	1	2	2	10
16. Consumer Repairability	1				1
17. Ease of Assembly	1				1
Additional Characteristics					
Device Availability	2			3	5
Training Availability	1			5	6

Table 4. Ranking of Device Characteristics from Batavia and Hammer (1990), Total Frequency of Occurrence of Characteristics, Ranking According to Frequency of Occurrence, and Average Rankings.

(1) Characteristics	(2) Batavia & Hammer Article Rankings	(3) Total Frequency of Occurrence from Other 28 Articles	(4) Ranking of Total Frequency	(5) Average of Column (2) & Column (4) Rankings
Effectiveness	1	4	13.5	7.25
Affordability	2	10	6.5	4.25
Operability	3	19	1.0*	2.00
Dependability	4	13	2.0	3.00
Portability	5	9	9.0	7.00
Durability	6	11	4.0	5.00
Compatibility	7	6	12.0	9.50
Flexibility	8	11	4.0	6.00
Ease of Maintenance	9	11	4.0	6.50
Securability	10	1	16.0	13.00
Learnability	11	9	9.0	10.00
Personal	12	9	9.0	10.50
Physical Comfort	13	7	11.0	12.00
Supplier	14	4	13.5	13.75
Physical Security	15	10	6.5	10.75
Consumer	16	1	16.0	16.00
Ease of Assembly	17	1	16.0	16.50

*Note: The highest frequency received a rank of 1

Kendall's Coefficient of Concordance (W) was used to determine the strength of relationship between two sets of rankings (Batavia and Hammer and Total) listed in Table 4. The value of W is a measure of association between k sets of rankings as ranked by different judges. W ranges from 0 to 1. A W of 1 shows perfect association; a W of 0 shows no association. The value of W for the set of 17 characteristics listed in Table 4 is .75 with an associated X^2 value of 24.2 ($p = .09$).

The list of 17 characteristics shown in both Tables 4 and 5 contain at least three outliers--Effectiveness, Physical Security, and Securability. Effectiveness was ranked first by Batavia and Hammer but was mentioned only four times in the other 28 articles. The most likely reason for this peculiar discrepancy is that Effectiveness encompasses many of the other characteristics. Physical Security was ranked very low by Batavia and Hammer, but it occurs frequently in the other articles. Securability was ranked fairly high by Batavia and Hammer but was listed in only one of the other 28 articles. Because of this diversity, these three characteristics were considered outliers and were removed, resulting in a set of 14 characteristics, which shared the most commonalities. The second calculation of Kendall's Concordance with 14 characteristics resulted in a W value of .89 ($X=23.1$, $p=.04$). Considering the diversity from which the frequencies and related rankings were derived, either value, $W=.75$ or $W=.89$, shows a surprisingly strong relationship between the two sets of rankings.

The characteristics in Table 4 are divided into two groups with the first nine characteristics in the first group and the second eight in the second group. Interestingly, the resulting characteristics within each group are the same for both rankings. These ordered groupings of

like characteristics also attest to the very close similarity between the two sets of rankings shown in Table 4.

Because there is some disparity of ranking within each of the two groups in Table 4, it is difficult to determine which characteristic may be more important than another within the same group. It appears, however, that ranking by group may be useful with the lowest group labeled Important, and the highest group labeled Most Important. The lowest group is considered important because merely being included in the synthesis means a characteristic has been selected as important by consumers and other experts. Using this rationale for determining importance by group, the final set of characteristics are contained in Table 5, ranked by group and alphabetized within group.

Missing from the priority listing in Table 4 are Training Availability and Device Availability. Neither Training nor Device Availability were mentioned in the Batavia and Hammer priority list but were listed in six other articles and are listed as key considerations by Guthrie (1984). Consequently, these characteristics are included in Table 5 as important characteristics.

Table 5. Device Characteristics Ranked by Group and Alphabetized Within Group

(1) CHARACTERISTICS RANKED AS MOST IMPORTANT	(2) CHARACTERISTICS RANKED AS IMPORTANT
Affordability	Consumer Repairability
Compatibility	Ease of Assembly
Dependability	Learnability
Durability	Personal Acceptability
Ease of Maintenance	Physical Comfort
Effectiveness	Physical Security
Flexibility	Securabilty
Operability	Supplier Repairability
Portability	
Important Characteristics Not Identified by Batavia & Hammer	
Device Availability	
Training Availability	

Limitations of the Synthesis

In an attempt to find relevant research articles and reports, three electronic literature searches were conducted. The first was conducted in June of 1992 using the descriptor "Physical Disabilities" and "Technology". Three additional searches were conducted in October 1992, March 1993, and September 1993 to explore additional descriptors and to find additional articles that may have been added since June. Proceedings from recent conferences such as those conducted by RESNA and on the extensive library of materials on AT assembled for the

Utah Assistive Technology Program were also used. As a result of all searches, 29 relevant articles were located, and only six of these articles actually describe a research study.

As noted by Galvin (1989), research is scarce in the area of using assistive technology in education and particularly as it relates to quality of devices. Consequently, we relied a great deal on descriptive reports containing information that is derived from expert opinion. Obviously, findings from this report would be more compelling if all the articles described research studies and all lists of characteristics were derived from research. At this point in time, however, a synthesis of research on AT devices would be based on very few studies.

Device Abandonment

An additional way to look at device quality, is to consider which characteristics contributed to the abandonment of devices. Realistically, a device would be considered effective only if a consumer continued to use an AT device in the face of continued need for AT. Phillips and Zhao (1993) conducted a study to determine why AT devices are abandoned and noted,

> A better understanding of how and why technology users decide to accept or reject a specific device is critically needed to improve the effectiveness of assistive technology interventions and enhance consumers' satisfaction with devices. (p. 36)

Phillips and Zhao (1993) go on to define the effect of abandonment:

> Technology abandonment can have serious repercussions. For individuals, non-use of a device may lead to decreases in functional abilities, freedom, and independence, and increases in monetary expenses. On a service delivery level, device abandonment represents ineffective use of limited funds by federal, state, and local government agencies, insurers, and other provider organizations. (p. 36)

The study conducted by Phillips and Zhao (1993) involved a survey completed by 227 adults with various disabilities. The survey was designed to collect information on device selection, acquisition, performance, and use. The purpose of the survey was to detect reasons

for abandonment of AT. The results showed that 29.3% of all devices were completely abandoned and that the following four factors were significantly related to abandonment: (1) lack of consideration of user opinion and selection, (2) easy device procurement, (3) poor device performance, and (4) change in users needs or priorities. Device performance was found to be the most important determinant of abandonment. Convenience of use, energy required for use, and required assistance from others were determined to be less important. The characteristics categorized under performance were; performed better (operability), reliability, comfort, ease of use, safety, and wear well (durability). These characteristics correspond closely to those identified by the research synthesis described in this report. They also found that a lack of training contributed significantly to technology abandonment. Phillips and Zhao (1993) contend that both rehabilitation professionals and consumers need more technology training. This contention is in agreement with the results of the research synthesis.

RECOMMENDATIONS

This section focuses on recommendations that will help designers and manufacturers improve the quality of AT. As noted before, the effectiveness of AT is dependent on the evaluation process used to select the AT device and on the quality of the device. However, the recommendations made in this report are confined to improving the quality of AT devices.

This section begins with recommendations based on the results of the synthesis contained in this report compared to recommendations made by other authors, followed by recommendations for universal design of all devices and appliances that may be used by persons with disabilities.

Recommendations for Designing AT Devices

The priority listing in Table 4 shows relative importance and is based on a consensus of research findings and expert opinion. As noted earlier, the degree of relationship (W = .75) between the contributors to this consensus is relatively strong.[2] This research synthesis, to a great degree, corroborates the findings of Batavia and Hammer (1990).

All of the AT device characteristics listed in Table 5 are important and should be considered by manufacturers, consumers and service providers as indicators of quality. The nine characteristics listed in column 1 of Table 5 should, however, be considered the most important characteristics. They were ranked the top nine in each set of rankings contained in Table 4 and are listed as key characteristics by Guthrie (1984) in his book Evaluating AT for Disabled Persons.

The characteristic Effectiveness encompasses many of the other characteristics. Effectiveness is generally defined as the extent to which the device meets the user's need and the extent to which the device performs as claimed by the manufacturer. Based on this definition, effectiveness cannot be determined prior to use by the consumer. However, a manufacturer should attempt to predict effectiveness by concentrating on the set of characteristics that may contribute to effectiveness. This set, excluding Affordability and Ease of Maintenance, is essentially those characteristics listed as most important in Table 5. Affordability, would however, be important in the determination of cost effectiveness.

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[2]Borg and Gall (1983) contend that correlation coefficients ranging between .68 and .85 make possible group predictions that are accurate enough for most purposes.

Any of the characteristics, if neglected by a manufacturer, could become a most important characteristic. For example, a device that was physically uncomfortable, very difficult to learn to use, or had an unacceptable appearance may be abandoned by the consumer and in turn become totally ineffective. Consequently, all of the devices listed in Table 5 should be considered important in the manufacture and evaluation of an AT device.

In considering the need for continuous quality improvement in the development of assistive technology, Russell (1993) notes the following:

> Assistive Technology is first and foremost a service business, and the priority of any service industry must be to listen and respond to what customers are saying. This may be even more critical in assistive technology programs given the unique and individualized needs of the consumer (p. 14).

Correspondingly Cohen and Frumkin (1987) suggest that the following questions need to be asked by the consumer and responded to by the developer:

(1) Is the documentation for the system complete, written in clear and concise language, and are all questions regarding the system included in the documentation?

(2) Is the manufacturer or developer easily available to the consumer to ask and answer questions that may arise concerning system operation or will additional consultation from other resources be necessary for the customer to fully understand the system design?

(3) Has the systems effectiveness and reliability been substantiated by research with the intended population?

(4) Are the systems designed using standard components, which allows for integration with other systems?

(5) Is the manufacturer's warranty, service policy, return policy, and cost notification sufficiently adequate to protect and direct the consumer?

(6) If the manufacturer or vendor helps evaluate the AT, are they knowledgeable about the nuances of communication disorders, physical disabilities, and disease processes?

Also with regard to service, the National Institute on Disability and Rehabilitation Research (1992) recommend that manufacturers of assistive technology should:

(1) disseminate product information to individuals with disabilities and service providers;

(2) evaluate product effectiveness with consumer input from persons with significant communication disabilities;

(3) provide warranties and timely product maintenance and servicing;

(4) ensure compatibility with other technologies;

(5) provide systems for trial use;

(6) work with researchers to facilitate technology transfer to the marketplace; and

(7) exhibit products and participate in seminars and conferences.

To ensure continued service and quality control, Russell (1993) recommends that manufacturers continually measure performance and suggests conducting consumer surveys. Russell includes specific criteria for designing a consumer survey (p. 15). He suggests that "Outstanding organizations have as one of their characteristics of dedication to measure a new performance in order to qualify the results and to improve their delivery of service" (p. 15).

The results of the synthesis contained in this report suggest that there is a set of characteristics that should be seriously considered when designing and manufacturing assistive technology. This set of characteristics is contained in Table 5. The synthesis also shows that selecting AT must be a team effort that includes the consumer in the decision making. Other authors who have made recommendations to manufacturers about designing and developing quality AT make similar recommendations.

The synthesis of information described in this report combined with recommendations from other authors provides sufficient evidence to warrant serious consideration to the priorities

assigned to the groups of characteristics listed in Table 5. When a manufacturer cannot give full attention to all characteristics because of limited resources, the priority list could be considered a guide for allocation of resources. At least one characteristic, safety, should always be considered even though it appeared relatively low on the priority list. Additionally, if abandonment can be anticipated, training, even though low on the priority list should always be considered.

Universal Design of Devices

The focus of this report has been on AT devices designed specifically for use by persons with disabilities. There are, however, design considerations that can help make all devices or products (not necessarily AT devices) accessible to persons with disabilities. Designing any product for a wide range of consumers is referred to as universal design. Attaining universal design requires attention to both the characteristics of the product (device) and the characteristics of the user. Matching these characteristics involves a concept called ergonomics.

Ergonomics is the process of determining how well a product's characteristics suit the user's characteristics; and from the consumers point of view, result in the following questions: Does it fit my hand comfortably? Is it easy for me to use? Can I use it safely? The essence of the questions is the emphasis on "I". In other words, does the product fit the needs of individual consumers and not the average consumer. Designing products that address these ergonomic considerations lead to universal design.

It is good business for designers and manufacturers to consider universal design, especially as it relates to persons with disabilities. This sector of the population is a rapidly growing market. The number of Americans with severe physical disabilities increased by more than 49%

between 1970 and 1981. This increase is attributable to medical advances and to an increased older population. Universal design is a win-win design approach. Persons with disabilities get a greater product variety and developers have a larger market.

Summary and Limitations

The selection and maintenance of AT devices is an ongoing assessment and training process involving an interdisciplinary team, the consumer or consumer representative, and manufacturer. The membership of the interdisciplinary team is dependent on the consumer's disability. The consumer and manufacturer should always be involved.

The manufacturer, in addition to designing and manufacturing the device, should be responsible for service, training and ongoing performance evaluation. A set of prioritized device characteristics is available to assist manufacturers design, manufacture and maintain quality AT devices. Serious consideration of these characteristics and other recommendations regarding service and training will help ensure quality AT devices for consumers and an expanding market for manufacturers.

The recommendations contained in this report are somewhat limited by the scarcity of research about the quality and effectiveness of AT devices. There is sufficient information, however, from expert opinion and clinical trials to provide guidance to manufacturers in their design and development of AT devices. This information should continually improve. Additional research is being conducted, and standards for quality AT are being developed by numerous organizations such as the United States Veterans Administration. Additionally, organizations such as the Rehabilitation Engineering Center at the National Rehabilitation Hospital have been established to evaluate AT devices.

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APPENDIX A

Definitions of Device Characteristics

Appendix A. Definitions of Device Characteristics from the Research of Batavia and Hammer (1990)

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	**Definition from Batavia & Hammer (1990)**
Effectiveness •Overall performance	The extent to which the functioning of the device improves the consumer's living situation, as perceived by the consumer, including whether it enhances functional capability and/or independence. •What does the manufacturer of the device claim the device will do? Does the device do what is claimed? •Does the device meet the specific needs of the consumer? If so, what specific needs are met and in what way? In meeting these needs, are other important needs compromised?
Affordability •Fundability •Reasonable cost	The extent to which the purchase, maintenance, and/or repair of the device causes financial difficulty or hardship to the consumer. •What is the price of the device? •Are there any hidden costs (e.g., installation costs)? •What are the likely costs of maintenance and repair? •Are the total costs of the device, including price, maintenance, repair, and any other costs within the consumer's means? Are they covered by public or private insurance (or other financing programs)? What share of the costs does the consumer have to pay out-of-pocket? •Are there any warranties on the device, and how do they affect the costs to the consumer?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Operability •Convenience •Easy to understand •Ergonomics •Requires assistance •Simplicity of use •Speed of response	The extent to which the device is easy to operate and responds adequately to the consumer's operative commands, including whether controls and displays are accessible and whether start-up time for each use is excessive. •Are the controls and displays easily accessible and usable? •How responsive are the visual displays in terms of viewing angles, colors, and shapes? How responsive are audible tones/alarms in terms of harshness, loudness, length, frequency, and understandability (e.g., speech or synthesized speech)? •What cyclical routines must be followed each day as the unit is used in the prescribed fashion? Does it need constant adjustment and/or excessive care in everyday use? Are there indications that the equipment is ready to use (e.g., meter readings, lights on or off, signals)? •Are there any tests or re-adjustments that need to be made as the equipment is used during the initial warm-up/use phase? •What portion of the turn-on/start-up routines must be followed each time the device is used? Is the start-up time excessive?
Dependability •Accuracy	The extent to which the device operates with repeatable/predictable levels of accuracy under all conditions of reasonable use. •Is the device dependable? What has been the prior breakdown history of these types of devices? Where was such information obtained? •Is any special room environment required (e.g., heating, cooling, dust-free)? Will low or high humidity cause problems? If so, what percentage of relative humidity is acceptable? Is the unit affected adversely by electromagnetic interference or power line "noise?" If so, by what levels? •What problems can arise if the equipment is not turned on and operated according to prescribed operating instructions? Can any permanent damage occur due to an improper action? If so, what actions will result in what kinds of damage? •Will the device remain dependable under repeated use?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Portability •Transportability	The extent to which the device can readily be transported to and operated in different locations, including whether the length of battery charge and the size and weight of the device permit physical relocation. •Can the device be transported easily to different physical and geographical locations without undue difficulty? Can it be carried comfortably or (in the case of long distance travel) transported in a car, train, or airplane? •If the device is powered by a battery, what is the length of the battery charge? •If the device depends upon an external power supply or other hook-up, will such hook-up be available in other locations? Can it be adapted to hook up in different locations?
Durability •Reliability	The extent to which the device will continue to be operable for an extended period of time. •What is the expected life of the device (i.e., how long will the device last before it can be expected to have significant dependability problems requiring frequent and expensive repairs)? •What level of care and maintenance is necessary for the device to last throughout (and beyond) its expected life?
Compatibility	The extent to which the device will interface with other devices currently and in the future. •Does the device operate independently or does it need to interface with other devices? •If it needs to interface with other devices, what are those devices? Is it currently compatible with such devices in the market? •Is the device likely to become obsolete in the near future due to compatibility problems with devices now being developed or contemplated?
Flexibility •Expandability	The extent to which the device is provided with available options from which the consumer may choose. •What options are available with the device? •Are these options important to the consumer? What is the cost of these options?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Ease of Maintenance •Maintenance requirements •Warranty	The extent to which the consumer (or his or her personal assistant) can easily maintain the device to keep it operable and safe, including whether it is easy to conduct all required maintenance, cleaning, and infection control procedures. •Is maintenance easily handled by the consumer (or personal assistant)? •How often are maintenance routines necessary? Are maintenance record forms provided? Are they adequate? •Are operation and maintenance manuals included with the unit? Does the instruction book spell out all maintenance routines to be followed? Are they effective? If not, in what ways are they deficient? •Are there adequate precautions for sterilization of the device (e.g., gas or steam) to prevent infection? What are the appropriate methods/chemicals for disinfection? Are specific cleaning procedures required?
Securability	The extent to which the device can easily be kept within the physical control of the consumer to reduce the likelihood of theft or vandalism. •Is the device easily secured so that it is difficult to steal? •Does it have any special features to enhance security?
Learnability	The extent to which the consumer, upon initially receiving the device, can easily learn to use it and can start using it within a reasonable period of time once assembled, including whether specialized training is required. •How long will it take for the consumer to learn to use the device effectively? •Are the operational instructions clear in terms of turning on the equipment, making any preliminary adjustments that are required, and allowing the equipment to warm up? •Is specialized training required? If so, how much training, and is it included in the price of the product? •How long should it take to run through all start-up and diagnostic routines that need to be done the first time? Can the consumer do these or must he or she have assistance?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Personal Acceptability •Appearance	The extent to which the consumer is psychologically comfortable when using the device in public (or in private), including whether the device is aesthetically attractive. •Would the consumer be embarrassed by any aspect of the device (e.g., physical appearance or unusual sounds)? •Is the design of the device compatible with the consumer's personality and lifestyle?
Physical Comfort •Ergonomics	The extent to which the device causes physical pain or discomfort to the consumer. •Does the device cause pain or discomfort? Does it make noises that are irritating to the ear or physical sensations that are irritating to the skin? •Does the consumer have to strain physically in using the device? Is it physically compatible with the consumer's body? •Does the device have special features to enhance comfort (e.g., a special seating system or shock absorbers in the case of a wheelchair)?
Supplier Repairability	The extent to which a local supplier or repair shop can repair the device within a reasonable period of time, including whether replacement parts are readily available and whether the manufacturer must conduct repairs. •If the device cannot be easily repaired by the consumer (or personal assistant), must it be returned to the manufacturer or distributor? What are the likely turn-around times of the most prevalent problems? •If the device typically can be repaired locally by a supplier or repair shop, what is the likely turn-around time? Are replacement parts readily available? Does it have any "built-in" diagnostic routines for fault determination? •Is a "hot-line" available to allow easy access to the manufacturer/distributor? If it is available, is the manufacturer/distributor responsive to calls?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Physical Security •Safety - electrical, mechanical, operational	The extent to which the device is likely to cause physical harm, including bodily injury or infection, to the consumer. •Is the device safe to operate? What are its safety features (e.g., emergency brakes)? •Are there any aspects of the device that are likely to cause physical damage or severe irritation, such as pressure sores? Does it disrupt internal physiologic functions (e.g., normal flow of blood or urine)? •Is the device likely to cause infection or other adverse physiologic reaction?
Consumer Repairability	The extent to which the average consumer (or his or her personal assistant) can repair the device if broken, including whether special repair equipment is needed. •What types of repairs can the consumer (or assistant) reasonably be expected to do, and what types of repairs must be conducted by an expert? •What, if any, education/training is required for the consumer or assistant to repair the device? •What, if any, special equipment is required to make any such repairs? •Does the unit have special design features (e.g., plug-in modules) that can reduce the difficulty of repairs? Have any spares been provided for this purpose?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Ease of Assembly	The extent to which the consumer (or his or her personal assistant) can easily assemble the device upon receiving it, including whether it is packaged conveniently. •Will the supplier assemble and/or install the device? •If not, what portion of the assembly or installation can the consumer (or personal assistant) reasonably be expected to do? Is a technician or engineer required for initial assembly or installation? •Are instructions for assembly and/or installation included in the manual? Are the instructions complete, concise, clear, and easy to follow (i.e., a logical step-by-step procedure)? •Are any special tools required for assembly, installation or start-up? Is any test equipment (e.g., computer, multimeter, oscilloscope) required for start-up or calibration? •Are other kinds of devices/furniture required to complete the system (e.g., special tables, wall mountings)? If so, will the supplier provide these?

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